Effect of AM Versus FM Screening on Ink Consumption on a Sheetfed Offset Lithographic Press

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Keywords

Coverage, FM, Ink, Mileage, Stochastic

Abstract: With recent advancements in computer-to-plate architecture, stochastic screening is now competing with traditional amplitude modified (AM) halftone screening in a wider variety of print applications. Proponents of stochastic screening (also known as frequency modulated (FM) screening) have claimed that, in addition to better quality reproduction and more consistent color, FM screening allows for lower ink consumption due to the frequency modulated dot structure. Lower ink consumption results in faster drying times, less anti-setoff powder required, and reduced cost.

This research project examined if a difference in ink mileage (consumption) exists between traditional halftone screening and stochastic screening. For this experiment, a four-color process test target with heavy ink coverage was imaged to plate twice at 175 lpi (AM) and twice at 10 microns (FM). The test form containing the AM and FM targets was constructed to eliminate variation due to lateral ink zone adjustments and inking system drop-off prior to the plate cylinder gap. The test form was printed in a single pass on the same sheetfed lithographic press using identical inks on 28 x 40 inch 80-pound basis weight (119 g/m^2) gloss coated paper. Solid ink densities were carefully controlled, with the AM and FM targets printed to identical target densities. The test was repeated at two lower densities using reduced inking to determine the effect of varying densities on ink consumption.

Printed sheets were analyzed for solid ink density and test targets weighed to determine ink consumption. The data showed that the test targets using 10 micron FM screening required measurably less ink than the identical target images using a 175 lpi conventional halftone screen

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when printed to identical standardized four-color process target ink densities. The difference in ink consumption between the AM and FM targets at reduced densities was significantly less.

The findings presented will be of importance to printers, ink and paper manufacturers, and manufacturers of computer-to-plate technologies.

Introduction

The concept of stochastic screening is not new; in fact it's inception can be traced as far back as the 1960's when Karl Scheuter began studies to prove that smaller dots in large quantities would reproduce an image better on a lithographic press. Two of Sheuter's students carried on his work for over almost three decades; however, it wasn't until computer-to-plate devices matured that stochastic (also known as frequency modulated) screening became a commercial reality. While the theory was accurate, prior to CtP it was extremely difficult to produce the fine dots on plate and maintain the consistency and repeatability needed for stochastic printing.

As the reliability and popularity of stochastic printing increases, so do the claims of companies that produce stochastic screening technologies. While some of the claims are relatively easy to prove (like better detail in small images and smoother tints), others have been less studied. For example, it has been suggested that stochastic screening actually broadens the gamut of color that it reproducible on press (Creo, 2002).

One such claim that the authors of this paper found interesting was that stochastic printing consumes less ink than conventional AM screening. At first, this claim may seem misplaced since it is usually ink film thickness that is associated with ink mileage, and ink film is controlled on press, not by the screening process. But what if the dot structure on plate affects how ink adheres to it? What if there really was less ink being applied to the paper? The implications of this could be very significant, and therefore worthy of investigating. As a result, the authors prepared a test to measure ink consumption variances between AM and FM screening. The authors designed a test that would eliminate any perceived potential for bias or process error. What follows is a detailed report of the experimental design, procedures, and the outcomes that resulted.

Glossary of Terms

The following is a list of general terms that relate directly or indirectly to the research performed for this paper. The definitions are formatted in such a way as to optimize their relevance to this report.

absorption. The property of a printing substrate that causes it to take up liquids and/or vapors which come in contact with it.

Amplitude Modulation (AM) screening. A screening process that consists of varying sized dots equally spaced apart. Generally measured in lines per inch (lpi), and can commonly range from 50 lpi to 200 lpi and higher. Also known as halftone screening.

densitometer. In printing, a reflective densitometer is a photoelectric instrument that is used to measure the density of ink colors on a substrate.

dot gain. A result of printing where the final dot on the substrate is larger than originally intended, resulting in darker tones and/or heavier colors in the final result. Total dot gain is a summation of mechanical dot gain (absorption of ink into the substrate) and optical dot gain (light refraction).

euclidean dot. A dot used in hafltone screening that starts as a small round dot in the highlight areas of the plate. It gradually morphs through the quarter tones until it reaches the 50% area, where it is becomes square and each corner touches the corner of an adjoining dot, causing a checkerboard appearance. The dot gradually morphs through the three-quarter tones until only small round dots of non-image area remain.

inking trail-off. A slightly thicker ink film laid onto the plate near the gripper edge and slightly thinner ink film toward the tail due to the plate cylinder gap and depletion of ink supply on the form rollers. This is largely, but not completely, eliminated by multiple ink form rollers of different diameters as part of sophisticated inking systems.

Frequency Modulation (FM) screening. A screening process that consists of equal sized dots of varying spacing. Generally measured in microns (µ), and can range from 10 microns to 40 microns. Also known as stochastic screening.

gray balance. The dot values of cyan, magenta and yellow, that when printed together produce a neutral gray.

gripper edge. The leading edge of a substrate as it passes through a lithographic offset press.

porosity. A property of paper that enables air permeation, and is important for ink penetration.

raster image processor (RIP). Hardware and software dedicated to translating vector PostScript or PDF data into raster data that in turn is used to drive the laser imaging head on an output device.

relative humidity. A percentage of the water vapor present in the atmosphere to the maximum water content possible in the atmosphere at a given temperature.

screen angles. Angles at which halftone screens are placed in relation to one another. A minimum of 30 degrees between colors is necessary to avoid moiré.

screening. A function of the RIP process that determines the tonal values of each dot for an output device on the basis of original pixel requirement from the file in order to create the laser-imaged dots. Screening is device dependant, meaning that each output device will render its own unique screening for output.

set-off. The transfer of ink from one printed sheet to another by physical contact and pressure or weight as sheets are stacked in delivery of the press.

spectrophotometer. In printing, an instrument that measures color values of ink on a substrate (usually in CIELAB L* a* b* values).

substrate. Any material that can be printed on, such as paper, plastic and fabric.

Research Design and Procedure

A significant amount of planning had to go into the methodologies of this project. First, a list of variables that could weaken the validity of the outcomes was assembled. While it is impossible to have laboratory control in a field experiment, eliminating as many of these variables as possible was of the utmost importance. After careful consideration, the authors identified the following variables as threats to validity and took actions taken to minimize that risk.

1. Design/Prepress Variables
    a. Image Area. The image area of the test form should have significant ink coverage to allow for measurable results.
    b. Plates. Plates should ideally be from the same lot number, output on the same device, processed with the

same equipment at the same time, and assessed for quality prior to use on press.

c. Output device must be calibrated.

d. The same RIP should be used to rasterize the files.

Stock variables

a. Weight discrepancy between sheets. Depending on where from the papermaking web the sheet was cut (left, right, middle), there can be slight variations in thickness or weight between sheets.

b. Humidity and moisture content. The amount of moisture in the paper will affect its weight; this is affected by manufacturing and ambient conditions.

3. Ink Variables

a. The same inks should be used for both AM and FM, and setting and drying time should ensure evaporation of solvents is equal on all test forms.

4. Printing Variables

a. Ink zones. The amount of ink may vary from one side of the sheet to the other due to ink zone settings

b. Inking trail-off. There is potential for the density of ink to be lower at the tail end of the sheet.

c. Fountain solution. The amount of fountain solution used on press will affect the weight of the sheet due to absorption.

d. Set-off. Any transfer of ink would affect the overall amount of ink on a given sheet

e. Set-off powder. Set-off powder has the potential of adding weight to the sheet.

f. Printing sequence. The sequence of colors printed could affect ink-film thickness due to wet-trapping.

g. Press speed. The press speed would have to be the same for both AM and FM to ensure consistent ink transfer and tack.

h. Print quality. The line screen ruling used for the AM test should be comparable in quality to the micron dot-size used in the FM test. High line screen = small micron dot.

5. Other Variables

   a. All solid ink density measurements should be made on the same instrument, at the same time, and in the same location on the sheet.

   b. All weight measurements should be made on the same instrument, at the same time, and in the same location.

   c. Any trimming of the test form should be done in a systematic way that will not influence the end results.

In the end, it was determined that running the test form so that both the AM and FM image were on the same press sheet helped resolve many of the listed variables.

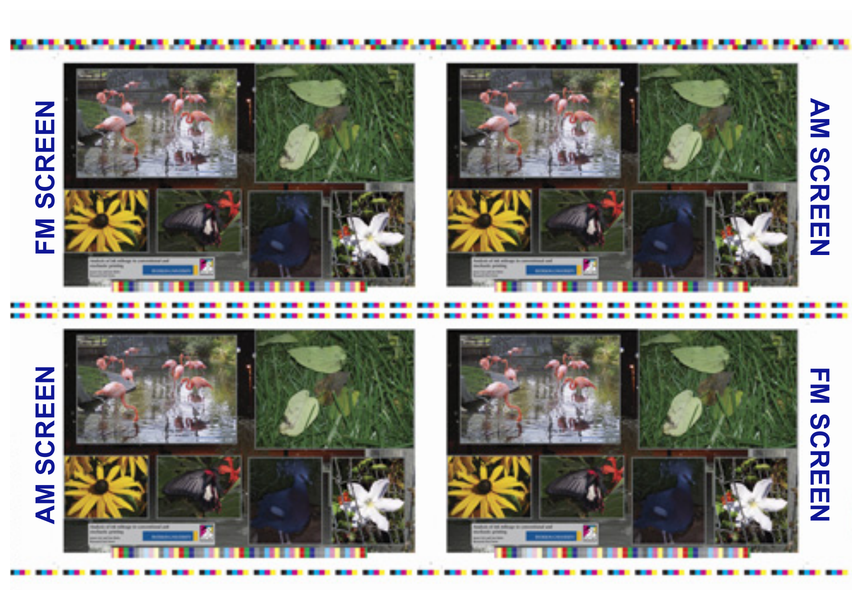

Figure 1. Running the test as shown above offset the concerns of ink zone variance, substrate variables, press run differentiations, and ink variables.

In particular, positioning the differently-screened images so that the like ones were on a diagonal from one another eliminated concerns about inking trail-off and ink zones. After printing, the press sheets were separated into bundles of five sheets. The average solid ink density of each bundle was measured using an X-Rite ATD scanning densitometer on the press control strip located on the tail edge of the sheet. Patches in margin and gutter areas that did not correspond to the test form were not included.

For this test, both the AM and FM screened images were output using linearization curves which adjust the image for optimal print reproduction. The researchers felt that printing to best practices was more relevant than printing non-linearized images because it would better replicate industry practice of obtaining the best visual output possible using a given screening technique. For example, total dot gain (optical and mechanical dot gain) tends to be heavier in stochastic screening. Also, the consistent dot-size of stochastic screening means that dot-gain is more likely to be constant (variations in dot gain do occur as a result of dots "chaining" and overlapping) through all tones, instead of increasing towards the midtone as occurs in halftone screening. Linearization overcame these variations and enabled us to have two visually comparable images that were representative of industry best-practice. Since many of the current printing standards (for example SWOP and GRACOL) are based on visually matching a specified target, it was valid to adopt similar practice for this test. The combined factors of the test form layout on the sheet combined with a close visual match of images when printed strengthened the overall validity of the test and its findings.

The press sheets were then trimmed to yield four identically-sized test forms (two AM-screened and two FM-screened) from each press sheet with a consistent margin of 0.25 inches around each form. Samples for weighing were assembled, with 5 FM cut forms from the top right-hand corner and 5 FM cut forms from the bottom left-hand corner combined and weighed together as a bundle of ten FM-screened forms. This was done 30 times for FM and 30 times for AM. The AM and FM forms originated from the same press sheets.

It was determined that an AM screen of 175 lpi would be comparable in quality to a 10 micron FM screen. That is to say, both are considered very high quality for commercial offset printing and representative of widespread "best practices" in their respective markets. Consequently, these were the values chosen to screen the job. The test form was designed with heavy ink coverage to enhance the ability to measure the weight of ink on paper. Also, each test form was designed with a white border around it to ensure no ink was accidentally cut-off on the guillotine.

It was decided that this job would be run at three different densities to determine if ink density affected the correlation between screening methods and ink consumption. To do this, the job was run at normal target densities for the first run, approximately 75% of normal target density of the second run, and approximately 50% of normal target density for the third run. The three press runs were completed consecutively on the same equipment and using the same materials without break. Target ink densities for all three runs are listed in Table 1.

Table 1: Target (Wet) Densities for AM versus FM Ink Mileage Comparison				
	Cyan	Magenta	Yellow	Black
1st Run (Full Density)	1.30	1.40	1.05	1.85
2nd Run (75% Density)	1.00	1.10	0.90	1.45
3rd Run (50% Density)	0.68	0.75	0.47	1.02

With the research design outlined here, the authors felt confident that every effort was made to account for variables that could influence the end result of the project.

Equipment and Materials Used

Table 2 displays an itemized list of equipment and materials used in this research project.

Table 2: Equipment and Materials Used		
Equipment	Description	Explanation of Use
Nikon CoolPix P1	8 Megapixel Digital Camera	Used to take the pictures used in the test form
Quark XPress 6.5	Page Layout Software	Used to create test form
Macintosh PowerBook G4	Laptop Computer	Used to store and assemble test form with Quark XPress
Power Macintosh G5	Desktop Computer	Used to Load and preflight test form files prior to printing
Creo Prinergy System	PostScript III RIP	Used to rasterize the test form
DynaStrip 4	Imposition Software	Used to Impose the printing Flat
Prinergy DotShop	Software that sets specifications for output resolution, screening, curve and dot shape to a PDF before output. It can be used with a selection of items in a	Used to divide the flat into AM and FM zones prior to screening

	page or the whole page. Only at output will the screening changes be applied.	
CREO Trendsetter	CtP Device	Used to Output the plates used for printing
Kodak Gold	Thermal CTP Plates	Used to print the test forms
Mercury Kodak	Plate Processor	Used to process the imaged plates (Kodak chemistry)
Glunz & Jensen	Preheat for plate development	Used to preheat the plates during processing
Wisconsin	Postbake for CtP plates	Used to postbake the plates after developing
Gretag IC Plate II	Portable Geometric Platereader	Used to measure plate accuracy prior to printing
Heidelberg Speedmaster 40	40" 6 color + coater sheetfed offset lithographic press	Used to print the test form. Ink sequence was KCMY.
X-Rite 528	Spectrodensitometer	Used to measure solid ink density during the press run
X-Rite ATD	Auto Tracking Densitometer	Used to measure solid ink densities post-run
X-Rite ATD v2.07 SP2	Auto Tracking Densitometer Software	Used to store measurements and create reports that include mean densities and standard deviation
OHAUS Scout Pro SP202	Analytic Scale	Used for measuring weight of printed and unprinted sheets
Polar 78	Guillotine Cutter	Used to cut press sheets into individual test forms
Microsoft Excel	Spreadsheet Software	Used to collect data, apply statistical analysis and graph results

Sample Data Gathering

During makeready and printing, press sheets were measured for solid ink density in accordance with plant quality assurance procedures with the goal being to achieve target ink densities across all ink zones in the four process colors. Following printing, makeready sheets were separated and disregarded.

After printing and ink drying, the sheets from the three press runs (100%, 75% and 50% of standard target ink density) were separated. Each press run was measured separately.

For each press run, 150 consecutive press sheets were separated into 30 sample bundles, each consisting of five consecutive press sheets. The average density of each sample bundle was measured using the X-Rite ATD scanning densitometer which measured solid ink density of all four process colors in all patches on the control strip located at the tail edge of the press sheet. Patches in margin and gutter areas that did not correspond to ink zones occupied by the test forms were disregarded and not included in subsequent calculations. For each sample bundle, the average solid ink density of each process color KCMY was recorded for later correlation with weight of printed forms.

After density measurements were completed, each press sheet was trimmed using a Polar guillotine cutter into four identically-sized test forms (two AM-screened and two FM-screened). Each test form included an unprinted margin of 0.25 inches on all four sides to ensure no image area was accidentally trimmed off.

After trimming, each bundle of five press sheets yielded 20 test forms – ten AM-screened and ten FM-screened, where forms using a given screening method were located diagonally opposite on the press sheet. The ten AM-screened forms were weighed as a single bundle as were the ten FM-screened forms. The net weight of each bundle was recorded in grams and hundredths of a gram. Weights of each bundle were correlated to the ink density records gathered by the scanning densitometer.

With the test form designed to eliminate any bias toward differential inking of the AM- and FM-screened test forms, and the sample sizes sufficient to reduce any effect of weight variations in the unprinted paper stock, any difference in weight of the printed AM-screened samples and the FM-screened samples can be attributed to weight of the ink due to a variance in ink consumption between the two screening methods.

The weight added by printing was determined by gathering and weighing 30 sample bundles of unprinted stock. The weight of sheets can increase during printing as a result of three causes: weight of printing ink, coatings and anti-setoff powder applied to the paper, weight of lithographic dampening solution applied to the paper, and any increase (or decrease) in moisture content of the paper during printing, drying or subsequent storage. In this project, anti-setoff powder, drying time and storage conditions were identical for the AM- and FM-screened forms; therefore, any weight difference between the AM- and FM-screened forms after printing and drying could not be due to paper moisture content. No press coatings were applied.

It is expected that the AM- and FM-screened forms absorbed a similar amount of lithographic dampening solution. During printing, the layer of fountain solution on the plate is only approximately 2 µm in thickness. Of this layer, some fountain solution evaporates, some is emulsified into the ink and some is printed to the substrate (Kipphan, 2001). Of the portion which is printed, it is expected that the drying time of five days was sufficient to allow most fountain solution to evaporate. It is likely that, after five days of drying, fountain solution did not account for the weight difference between AM- and FM-screened forms.

In order to correlate the variables of ink volume and weight, scatter graphs were generated. The mean total solid ink density of each sample bundle of 10 test forms (as a percent of full density mean) was plotted on the x-axis. The weight in grams of the sample bundle was plotted on the y-axis.

This analysis accounted for the variation in solid ink density that occurs during a press run. The press runs to target ink densities generated the following average ink densities after drying.

Table 3: Average Ink Densities after Drying

	Cyan	Magenta	Yellow	Black	Sum of Densities	Percent of Full Density
1st Run (Full Density)	1.36	1.43	1.00	1.80	5.59	100.00
2nd Run (75% Density)	0.97	1.06	0.78	1.32	4.13	73.92
3rd Run (50% Density)	0.67	0.80	0.50	0.98	2.95	52.65

For each sample, solid ink density of CMYK was measured and calculated as a percentage of sum of the grand average (5.59) of all samples printed to full density.

Results and Discussion

The results showed that the weight added by printing ink to paper was measurable. The average weight of 10 unprinted blanks was 144.60 g. For test forms printed in the first press run (100% of target solid ink density) 10 AM-screened forms weighed 146.52 g while 10 FM-screened forms weighed 146.08 grams, a difference of 0.44 grams, or 1.78 AM standard deviations. Significantly, the FM-screened image consumed 22.9% less ink by weight than the AM-screened image when printed to normal target ink densities.

Table 4: Weight and of 10 Test Forms (Average of 30 Sample Bundles)				
Dry Ink Density	AM Screen		FM Screen	
	Weight (g)	Std. Dev.	Weight (g)	Std. Dev.
Blank (unprinted)	**144.60**	0.40869	**144.60**	0.40869
1st Run: 100% of Target	**146.52**	0.24703	**146.08**	0.31039
2nd Run: 73.92% of Target	**145.79**	0.41392	**145.69**	0.43792
3rd Run: 52.65% of Target	**145.26**	0.34337	**145.23**	0.34841

For test forms printed in the second press run (73.92% of target solid ink density) 10 AM-screened forms weighed 145.79 g while 10 FM-screened forms weighed 145.69 grams, a difference of 0.10 grams, or 0.24 AM standard deviations. For test forms printed in the third press run (52.65% of target solid ink density) 10 AM-screened forms weighed 145.26 g while 10 FM-screened forms weighed 145.23 grams, a difference of 0.02 grams, or 0.06 AM standard deviations.

Standard deviations were relatively consistent across all three press runs and the blank forms. In each case, the weight of AM-screened forms had a slightly smaller standard deviation than the FM-screened forms.

Analysis of results shows that at all three density targets, the forms printed with FM screening consumed less ink by weight than those printed with AM screening; however, the difference was much less than at full standard production ink densities, as seen in the scatter graph on the next page.

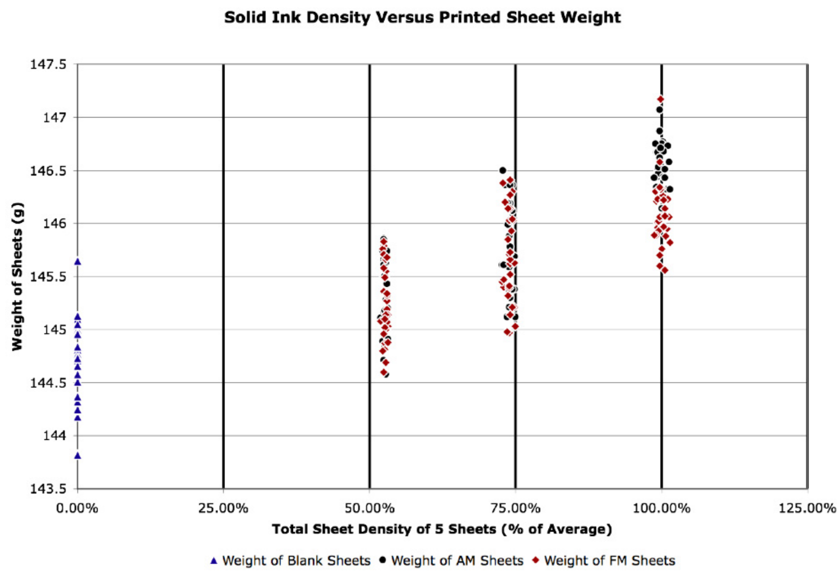

Figure 2: Scatter graph of Solid Ink Density versus Printed Sheet Weight for AM- and FM-screened test forms

The scatter graph shows that the weights of printed forms are discretely clustered when printed at standard solid ink densities; however, at reduced ink densities, the plots are intermingled.

The effect of solid ink density on ink consumption is well illustrated in the line graph below (see Figure 3). Both the AM and FM sheets start as blank sheets at the same average weight. As solid ink density increases, the difference in ink consumption grows. The explanation for this result has yet to be determined; however, one theory the authors are pursing is a relationship between dot size and surface tension of the ink. In theory, each dot will have a maximum amount of ink it can hold. Since AM dots bigger than 10 micron have a greater surface area, they are likely to be able to hold a greater volume of ink (Figure 4). This is an area for future research.

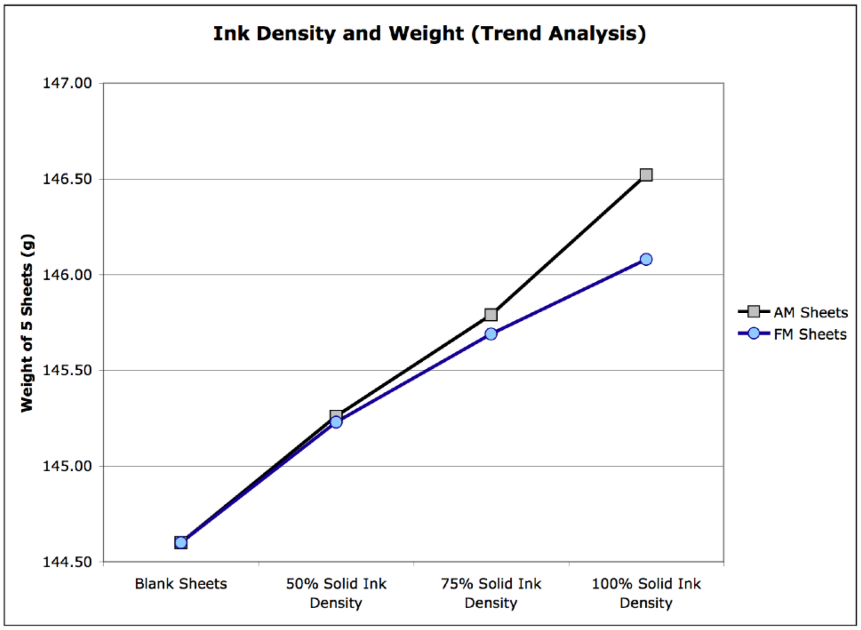

Figure 3: The correlation between solid ink density and ink consumption with AM and FM screening.

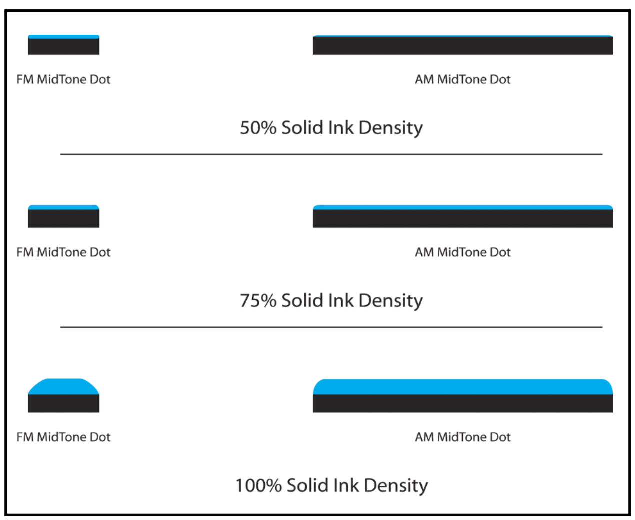

Figure 4: The relationship between surface tension of ink and the size of dot on press may explain the results reported, however further research is required to validate this hypothesis.

Conclusion

The data indicate that claims of reduced ink consumption for FM screening appear to be valid. In this test, the FM screened images consumed less ink than the AM screened images when printed to standard solid ink densities.

Implications of reduced ink consumption are several. For long press runs, measurable ink savings can be achieved using FM screening. This test revealed a savings of 0.44 grams of ink over 10 test forms. Since each test form represents approximately one-quarter of a 28 x 40 inch press sheet, the ink saved was 0.44 grams per 2.5 press sheets. On lengthier runs with images requiring similar ink coverage, the ink savings could be 1.76 kg on 10,000 sheets, 17.6 kg on 100,000 sheets, and 176 kg on 1 million sheets. At typical standard ink density, the ink consumption of the FM-screened test form was 22.9% less than that of the AM form.

In fact, it is likely that the actual ink savings with FM screening are greater than our results show because the sheets in this research were weighed after a drying period of five days. During this drying time, some of the solvents would have evaporated from the printed ink film, lessening the weight difference between AM- and FM-screened test forms. Since ink is purchased by weight inclusive of all constituents before drying, it is possible that actual ink savings could be greater than our results indicate.

Organizations contemplating the decision whether to apply stochastic screening for a particular workflow or single job can make the decision with a more complete understanding of ongoing costs involved, knowing that ink consumption can be expected to decrease with stochastic screening. While ink costs are only a small portion of the overall cost of a printed job, and the choice of screening method will be based on many factors, the cost of ink should not be ignored. Additionally, some printing inks such as metallic colours are particularly costly and the savings from using stochastic screening would be greater.

Additional implications beyond cost are the environmental benefits of using less printing ink. Further research is needed to examine if the reduced ink consumption with stochastic screening equates to less propensity for ink setoff, reduced drying time, or faster job turnaround.

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